EXPLORING SUSTAINABILITY, OPERATIONAL EXCELLENCE AND ECO-FRIENDLY ENVIRONMENT THROUGH SIX SIGMA IN FOUNDRIES: A SELECT STUDY IN AGRA FOUNDRIES

SYNOPSIS

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1.0 INTRODUCTION

Iron foundries in India have been playing inevitable role in the industrial development. The product of these foundries is used as raw material for almost all types of industries. But today, these foundries are facing lot of problems and the major ones are the restrictions imposed by the Central Pollution Control Board (CPCB) regarding emissions level table (1.1) and energy consumption limits imposed by TERI (The Energy and Resource Institute) (table 1.2).

S. No.	**Particulars of unit operation**	**Pollutants**	**Concentration Mg/m^3**
1.	For melting rate < 3Mt/hr Cupola furnace	SPM suspended particulate matter	450 Mg/ m^3
2.	For melting rate > 3Mt/hr	SPM	150 Mg/ m^3
3.	Burnt sand particles adhering the foundry remelt	Coarse solids	+44 microns
4.	Finely divided material	Fine particles	2 to 44 microns
		NO_x	120 Mg/ m^3
		SO_2	120 Mg/ m^3
		Noise level	Day-75db Night-70db
		Lead	1.5 Mg/ m^3
		CO	5.0 Mg/ m^3
		CO_2	4.0 Mg/ m^3
		O_3	100-120 Mg/ m^3
5.	Fans, power systems, Blowers	Color, fumes water droplets	NIL
6.	New Cold Blast furnace	Grit, dust, fumes	100 Mg/ m^3
7.	Existing cold Blast Plants >4MT/hours	Pollution control equipment must be installed for SPM, SO_2, NO_X, CO, CO_2 etc.	115 Mg/ m^3 (Max)

Table - 1.1: C.P.C.B Emissions standards for Cupola furnace (2008)

As per the survey conducted by and reports published by several national and international agencies the energy consumption in Indian ferrous foundries is much above the required limits and has to be reduced drastically.

S.No	Description	TERI limits
1.	Average specific energy consumption in foundries (a) using electric furnaces (b) using coke fired furnaces (c) using oil fired furnaces >1 ton/hr <1 ton/hr	 3400MJ (944.5 KWh)/tons 3400MJ (944.5 KWh)/tons 7000MJ (1805.55KWh)/tons 8000MJ (2221.60Wh)/tons

Table - 1.2: TERI limits for energy consumption (in melting only) (TERI Year and Data book 2009)

Because of this, most of the iron foundries where coke fired cupola is used for casting are under severe stress. Agra was having about 350 cast iron foundries producing quality castings with a tremendous turnover. Apart from foundries, Agra was also having large number of small workshops used for finishing the castings to use it for further required work.

For very high levels of pollution in Agra, one of the important causes was the effluents from the cupola based foundries. As per the reports of TERI, these foundries showed tremendously high emission levels. In most of the foundries, analysis of exhaust gases indicated the average Suspended Particulate Matter (SPM) level equal to about 1500 mg/Nm^3 which is roughly ten times the permissible limits. These pollutants from the foundries not only adversely affected the texture of white marble of the Taj Mahal but also affected the human health very badly.

The exhaust gases emitted having pollutants violated the Clean Air Legislation Act. Accordingly with the order of Honorable Supreme Court (1996), the government in 1997 banned the use of coke fired cupolas in the foundries which affected approximately 3 lakh people depending on these foundries directly or indirectly. The suggestion made was to use Natural gas fired cupolas but the basic cost for gas fired cupola was about 50-65 lacs which was beyond the reach of most of the small scale foundry owners. At the same time there was acute problem of gas supply from Gas authority of India (GAIL). Also the cost was increasing very high by using pollution control equipment in the cupola furnaces.

So, need for the use of advanced scientific design of the furnace was felt. This design should satisfy the environmentalist and also regain the lost pride of Agra for its foundries without having any adverse effect on human health. For which a vast survey of cast iron foundries was conducted in Agra for the quality of the final castings required. The melting process using electric arc furnace, plasma arc furnace, laser furnace, coke-less cupola and induction furnace, due to their high cost of installation and operation have been negated for their adoption in small scale foundries, particularly in Agra. On the basis of use, experts from the foundries identify the parameters influencing the melting process Multi Criteria Decision Making (MCDM) tools were applied to select the optimal melting technique and the best fuel to be used. Radhakrishna (2009) stated that Rotary furnace fired with blends of LDO (Light Diesel Oil) and 10-20% of bio-diesel was found to be best alternative. Various parameters were optimized by conducting exhaustive experiments.

Rotary furnace was found to be the best alternative considering the initial installation cost involved and the present day economic demand, so that production capacities be optimized with least possible down time, low maintenance cost etc. Studies were conducted on this furnace with LDO and LDO blended with bio-diesel as fuel but all the pollutants were found very close to CPCB norms. The only drawback found in the rotary furnace is its poor energy efficiency. So, if this furnace is to be used as an alternative to Cupola, certain design modifications are to be made to make the furnace more energy efficient and to enhance its performance. Some heat recovery device is required to be added in the furnace to increase the inlet temperature of the air entering the furnace. For which a heat exchanger will be designed, fabricated and used in the furnace to make it energy efficient.

Casting is a complex process and involves the interactions of many interdependent casting process variables. Green sand casting is one of the most widely used manufacturing processes for producing a variety of parts. It has been recognized that green sand casting parameters design plays one of the key elements in casting quality. Defective casting leads to tremendous loss of productivity. Despite being world's second largest producer of castings, Indian foundry

industry has failed to keep up with the domestic demand (both in terms of quantity and quality) because of alarmingly low productivity levels. For global competitiveness, this industry must strive hard to achieve overall operational excellence in business and so ought to look for flexibility, shorter lead time and defects reduction, because only such a configuration of production system can fulfill the customer expectations. Six Sigma is one of the more recent quality improvement initiatives to gain popularity and acceptance in many industries across the globe. Six Sigma is a new management strategy under leadership of top level management to create quality innovation and total customer satisfaction. It provides a means of doing things right at the first time and to work smarter by using data information. Six Sigma methodologies are more comprehensive than prior quality initiatives such as Total Quality Management (TQM) and continuous quality improvement (CQI).

In the present study improvement in the existing rotary furnace is required to make it energy efficient, producing quality castings at the cheap rate in an eco-friendly environment and employing Six Sigma tool for productivity enhancement and operational excellence.

2.0 LITERATURE REVIEW

Detailed assessment of foundries in Agra has been done by Radhakrishna (2004) and indicated very high amount of pollution levels almost ten times the allowable limits. Besides causing environmental damage and health hazard due to excessive pollution, these pollutants tarnished the pristine white marble of the Taj Mahal. In view of this, Honorable Supreme Court of India ordered the closure of these polluting foundries forcing them to look for alternative, environment friendly and economically viable alternatives. Various alternatives were evaluated and Radhakrishna (2009) stated that small scale foundries cannot make high investment on furnaces such as gas operated Cupola. He further stated that laser furnace and the plasma arc furnace using state-of-the-art technologies costs more and the crucible furnaces emit pollutants. So, rotary furnace is the only plausible alternative for melting iron in the foundries. The economy of producing casting is very important and economic justification of the Coke-less

Cupola for pollution free casting in Indian environment with special reference to Agra was given by Singh et. al. (2000) and further it is presented by Singh (2001) that Rotary furnace is an efficient answer to produce castings in a pollution free environment. Various parameters that control the quality and composition of molten metal play a significant role in determining the molten metal properties and should be controlled throughout the melting process. Certain modifications done by Radhakrishna (2004) indicated huge profit in overall manufacturing of castings.

Economic evolution of gas-fired cupola furnace; induction furnace; rotary furnace done by Radhakrishna (2009) pointed out that the rotary furnace is the most suitable furnace as the cost of producing castings is minimum and pollution level is also drastically reduced. It has been observed that the energy requirements in the rotary furnace are very high whereas Jain and Gupta et al. (2007) are of the opinion that the techniques for energy conservation must be adopted further adding new energy input may be a remote future possibility but immediate need is to save the energy.

It has been reported by Radhakrishna (2009) that emission level of rotary furnace with LDO are not with in the CPCB limits. The amount of sulphur is very high, which is the root cause of the decay of the Taj. Energy consumption is found more than the other furnace. Hence, the castings were tried by blending LDO with some alternative fuel and observed that blending of 20% bio-diesel with LDO brought down the level of sulphur but other pollutants were very close to CPCB norms. So, a modification is required to make the furnace energy efficient and totally pollution free. Apart from pollution, the foundries are also suffering from productivity loss and poor operational excellence.

So, for improving productivity levels and quality of castings some quality improvement techniques are to be applied for enhancing production and operational excellence in the foundries.

Six Sigma has grown out of traditional Quality Management (QM) methods and many traditional QM practices are recognized as important tool for Six Sigma implementation. Researchers have identified many critical dimensions or elements of Six Sigma programs, such as management involvement, improvement specialists, performance metrics, a systematic procedure, and project selection and prioritization. There are two major improvement methodologies under Six Sigma umbrellas. Define, Measure, Analyze, Improve and Control (DMAIC) is used for continuous improvement on already existing products/processes and Design for Six Sigma is used for designing new products/processes.

Six Sigma is an organized and systematic method for strategic process implemented and new product and service development that relies upon the statistical method and scientific methods to make the dramatic reduction in customer defined defect rates. Hence, it has been used as a tool for organizational process change. It is also popularly used as an extension of other quality improvement techniques. Johnson (2002) observed that in Six Sigma programme model, company resources used so as to increase the loyalty of customers and other stakeholders in the organization to meet the corporate objectives will be surpassed. Chakravorty and Hales (2004) found that the first step in implementing a Six Sigma programme was to perform a customer and market driven strategic analysis. This analysis was to direct the operational improvement effort to gain the competitive value in the market. Sinha and Van de Ven (2005) stated that assigning the improvement effort to take different levels of roles and responsibilities in leading the continuous implementation of Six Sigma efforts, the organization builds a Six Sigma role structure for quality improvement. Hence, Six Sigma is used as a Tool for implementing a management strategy.

Antony (2007) observed that the main benefit of a Six Sigma programme is the elimination of subjectivity in decision-making, by creating a system, where everyone in the organization collects, analyzes and displays data in a consistent way. It is already a proven fact that the benefits obtained from Six Sigma implementation outweigh the investment costs. It has been seen that six sigma has been used with lot of advantages. Chookittikul and Chookittikul (2008)

discussed the benefits and future of Six Sigma approach. Authors focused on understanding the key features, obstacles and shortcomings of the Six Sigma methods and allow organizations to better support their strategic directions and increasing needs for coaching, mentoring and training. It also discussed the opportunities for better implementation of Six Sigma projects. They examined the evolution, benefits and challenges of Six Sigma practices and identified the key factors influencing successful Six Sigma project implementations. But it is very important to know the root causes of the quality problems and Dai (2008) carried out experimental investigation to find the root causes of quality problems and to implement results, Author reported on how Six Sigma can benefit both big and small companies. It was stated that Six Sigma methodologies was first implemented to improve manufacturing, the method can also be used in other business strategies, such as product design and supply chain management. Cost improvement, customer's satisfaction and valid strategy performance are the key factors to promote the enterprise improvement ability. Lee and Chang (2010) explored that Six Sigma systems can promote the enterprise improvement ability, such as pursuing cost improvement, promoting quality, the customer's satisfaction and valid strategy performance. Deshmukh and Lakhe (2010) stated that Six Sigma helped many industries, small and big to achieve phenomenal success.

Six Sigma has been implemented in different sectors such as non-manufacturing and manufacturing.

2.1 Non-Manufacturing Sectors

Hospital industries are one of major active non-manufacturing sector in which Six Sigma methodology is adopted. Butler et. al. (2001). Benedetto (2003), McFadden et al. (2004), Thor et al. (2007) ,Pan et al. (2008) Boaden et. al. (2008), Mandahawi et al. (2010), Meulen et. al. (2011) etc. applied Six Sigma in Healthcare and Hospital industry. Bolt et al. (2000), Doran (2003), Uprety (2009) Fraser (2009) explored the use of Six Sigma methodologies applied to

Financial sector/Banking industry. Similarly Six Sigma has also been applied in R&D, Service Engineering and construction sectors.

2.2 Manufacturing Sector

Six Sigma has been implemented successfully in many manufacturing industries such as for streamlining the process and optimizing the cost and schedules of the telecom project Moreton (2003). Garg et. al. (2004) investigated on robust optimization in high-temperature superconducting (HTS) cable based on particle swarm optimization with differential evaluation operator (DEPSO) and design for Six Sigma. Authors utilized an improved particle swarm optimization, which is hybrid traditional particle swarm optimization (PSO) with the standard PSO, and it has proved that DEPSO provides a better performance than PSO. Six Sigma has been successfully applied on the effect of technological effect on working relationship Patnano et al. (2006). Author studied the effect of technological intensity on the relationships among Six Sigma programme design factors, e-business applications and Six Sigma application (SCA) for the manufacturing and service organizations. Rao et. al. (2009) stated that in the present era of globalization, where for the production units it is very tough to survive in the market gets tougher as there is much pressure on manufacturing to become more productive and efficient. Manufacturing organizations need to improve quality, while reducing cost and boosting productivity with limited resources. Six Sigma approach can directly fulfill these requirements, if implemented judiciously.

The researchers have also worked in the area of implementation of Six Sigma in the foundries which is summarized below.

2.2.1 Foundries

The foundries are most economical routes to produce metallic components in which the molten metal is directly poured into the mould cavity of required size and shape. The major problem in casting process is the generation of casting defects such as porosity, crack, shrinkage, blowholes etc. A lot of research was carried out on green sand and its properties about 1970’s around the

world. Most of the research work during that period was experimental and theoretical approaches. A large number of experimental investigations linking green sand casting parameters with casting quality have been out by researchers and foundry engineers over the past few decades. Several new statistical tools and concepts of quality improvement that depends heavily on the statistical theory of experimental design have been introduced by Taguchi and Clausing (1990). Magmasoft, a commercial finite difference solver for the simulation of casting was used for study of castings at very high levels. Lipinski et al. (1991) presented the numerical basis of Sulaiman and Gethin (1992) used a network for metal flow analysis in the pressure die casting process to predict the metal flow characteristics in the filling system by simplifying the complex Navier-Strokes equation. In Die casting significant process parameters were analyzed to obtain the optimum settings for getting the optimum density of aluminum alloy by Syrcos (2002). Since, it is very important to improve the quality without increase in price which is influenced by cost of production which in turn is influenced by rework or rejection. Vijayaram et al. (2006) expressed that attention to quality assurance can reduce wasteful rework. Thus, quality production results in foundry's growth and profit. Kumaravadivel and Natranjan (2013) used Six Sigma DMAIC methodology to improve sand casting process with response surface technology. Penalty based approach has been proposed by Ransing .et. al. (2014) where deviation from the desired process response is penalized and the penalty is transformed onto related process parameters. Six Sigma as a path breaking methodology for the business improvement has its own advantages, disadvantages and limitations.

2.3 Advantages of Six Sigma

a. Six Sigma is driven by the customer and thus aims to achieve maximum customer satisfaction and minimizing the defects. It targets the customer delight and new innovative ways to exceed the customer expectations.
b. Implementation of Six Sigma methodology leads to rise of profitability and reduction in costs. Thus improvements achieved are directly related to financial results.

c. Six Sigma is successfully implemented in virtually every business category including return on sales, return on investment, employment growth and stock value growth.
d. Six Sigma targets Variation in the processes and focuses on the process improvement rather than final outcome.
e. Six Sigma is prospective methodology as compared to other quality programs as it focuses on prevention on defects rather than fixing it.
f. It is attentive to the entire business processes and training is integral to the management system where the top down approach ensures that every good thing is capitalized and every bad thing is quickly removed.

2.4 Disadvantages of Six Sigma

a. Applicability of Six Sigma is being argued among the Six Sigma critics. They opined that the quality standards should be according to specific task and measuring 3.4 defects per million as standard leads to more time spent in areas which are less profitable.
b. Six Sigma gives emphasis on the rigidity of the process which basically contradicts the innovation and kills the creativity. The innovative approach implies deviations in production, the redundancy, the unusual solutions, insufficient study which are opposite to Six Sigma principles.
c. People argue that Six Sigma is a bit gimmicky and simply a rebranding of the continues improvement techniques and tools as practiced by Toyota. It thus promotes outsourcing of improvement projects with lack of accountability.
d. Six Sigma implementation constantly require skilled man force. Thus control and employee dedication are hard to accomplish if it's not implemented regularly.
e. While converting the theoretical concepts into practical applications there are lot to real time barriers which needs to be resolved.

2.5 Six Sigma limitations

There is immense popularity and the wide-spread adoption of Six Sigma, at the same time there is an amount of concern across industries regarding the failure of Six Sigma programmes.

Gopal (2008) found that one reason of failure of Six Sigma implementation in many companies was due to the lack of commitment from management. Management simply pushes Six Sigma programmes out to employees and did not personally involved in the implementation process. Despite the pervasiveness of Six Sigma programme implementation, Chakravorty (2009) stated that there is rising concern regarding the failure of many Six Sigma programmes. One explanation for many Six Sigma failures could be escalation of commitment.

India has 4600 foundry units, 80% of them in SME sector. The sector employs 0.5 million people directly and an additional 1.5 million people indirectly. The industry is making a contribution of Rupees 7000 per ton produced to National exchequer by way of Excise and other levies. The manufacturing units are located in 12 identified and recognized clusters and besides this, a number of units are staggered throughout the country due to lack of awareness. Approximately, 32% output of foundry industry goes to auto industries and rest to other downstream engineering sectors. The performance of Indian foundries has been highly dismal as shown in Table 2.1, which compares their performance indices with those of other countries. Poor operation management, lack of serious R&D support, low capacity utilization etc. has been the major reasons for this low productivity level.

Performance Norms	Indian Foundries	Overseas Foundries
Production per annum (%)	8 to 9	92 to 93
Rejection (%)	10 to 25	2 to 12
Capacity Utilization (%)	45 to55	60 to 75
Productivity (T/Man/Year)	12 to 20	100 to 120 (Japan) 50 to 55 (Germany) 10 to 30 (China)
Energy Requirement (KWH/T	700 to 900	400 to 600

Table-2.1: Comparison of Indian and Overseas Foundries

After an extensive literature review, need for energy efficient furnace following CPCB norms producing quality castings at the low price is evident and it also appears that the application of Six Sigma in the areas other than the big multinational companies has been rare and inconsistent. Little evidence exists in literature on Six Sigma implementation in foundry industry, which is counted as the most important supplier/feeder to other manufacturing industries. Defects generated are the main drawback of casting industry. Defective castings lead to tremendous problem in productivity. Since this industry is facing serious sickness levels, an attempt can be made to implement Six Sigma over various systems and sub systems to considerably improve the productivity and profitability levels. Literature also reports tremendous financial gains through Six Sigma in large manufacturing sector, so an attempt can be made to replicate it in foundry SME sector too. To cope up these challenges, massive micro level implementation of Six Sigma seems to be a highly feasible solution for these foundries. Hence it appears that there is dire need of inventing new business improvement strategies and better tools/techniques for enhancing productivity levels.

To further aggravate this scenario, Automotive Mission Plan (AMP) 2006-2016 of India has put tremendous pressure on foundry units because restriction on emission levels laid by the central pollution control board (CPCB), foundry units of the country and Agra in particular are finding it difficult to survive and to meet the steep demand of Indian auto industry. On the other hand, Globalization policy of India has made it possible to permit the Auto giants like Honda, BMW, Hyundai, Nissan, Ferrari, Toyota etc. to enter Indian market by establishing their production units in India. The demand of the quality products from these quality conscious global industrial units paving the way to increase the import rate of the castings and the future trend seems to be alarming.

Review of the literature indicates that much attention has not been paid to the following aspects in foundries.

- **Furnace used is not energy efficient.**

- **Pollution levels are very close to CPCB but all are not within the limits.**
- **Foundries suffering from productivity loss, quality and poor operational excellence.**
- **Little evidence is available in literature on Six Sigma as a tool for quality and operational excellence in foundries.**

Hence there is dire need of devising serious strategic measures to produce the quality castings at low price in an eco-friendly environment conforming to CPCB norms to reestablish the foundries in TTZ thereby avoiding negatively affecting the socio-economic status of all those involved. Also there is tremendous need to increase the operational excellence of Indian foundries and this research work would be an exploration in this direction as this will be an effort on testing some Six Sigma imperatives for enhancing production and operational efficiency in Indian foundry environments with special relevance to Agra. Serious lack of expertise on implementing Six Sigma tools and methodologies across a wide range of processes or organizations needs a real rethinking. The present research work proposes to adopt case study based approach to achieve the pre-defined goals and objectives relating to energy efficiency, pollution levels and, Six Sigma implementation in Agra foundries. The results can be comfortably replicated for foundries in other regions of the country. In this context Six Sigma can be a powerful business improvement strategy that enables industry to use simple but powerful statistical methods for achieving operational excellence. Keeping this in mind, the present research proposal dwells on exploring the synergy of Six Sigma and foundry industry and analyzing its possible strategic impacts.

3.0 OBJECTIVES

To formulate a comprehensive strategy for exploring the synergy of six sigma and foundry industry to enhance the productivity levels (without ignoring its existing constraints).

Primarily the major objectives of the present research work are:

1. To protect the World Monumental Heritage of Agra from the pollutants emanating from the foundries by using rotary furnace with design modifications to produce castings at a competitive price in an eco-friendly environment to stand in the global market.
2. Identification and classification of various elements in the casting process of foundries and elements in the six sigma tool kit to discover the root cause underlying the problem and prioritize action.
3. To formulate a comprehensive strategy for the successful implementation of Six Sigma in casting section of Agra foundries to improve the productivity levels.
4. To provide standard step by step framework to execute different phases of DMAIC project in casting section of Agra foundry environment, to reduce scrap/reworks/rejects.
5. Comparison of predicted output and experimental observations of various defects responsible for the poor productivity level will be done and will be validated using ANN and regression modeling.

4.0 EXPECTED OUTCOME OF THE PROPOSED RESEARCH WORK:

1. The outcome of this research will also help in rehabilitating the foundries of Agra in particular and across India in general, which are closed due to high operational cost and emanation of pollutants.
2. Presently, in India the productivity index is quite low in foundries and this study shall help in exploring various analytical tools/techniques to be used more strategically and in a more applicable form for enhancing the productivity index.
3. This research work would greatly help in improving the sustainability of units by enhancing the production efficiency of the system and significantly help to reaffirm the efficacy of Six Sigma strategy in Indian foundry industry to reduce wastage from the different operations.
4. The possibility of development of high temperature of the melt will make Agra foundries possible to produce different grades of quality castings including SG iron castings at competitive rates to cater to the needs of global market.

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